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Air-Ground Integration: Preliminary Results from the Coalition Attack Guidance Experiment

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Air-Ground Integration: Preliminary Results from the Coalition Attack Guidance Experiment

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Abstract

Military operations are experiencing an increase of airspace usage which in turn increases the airspace management challenge. In response to this change, new technology and tactics, techniques and procedures (TTPs) are required. The Coalition Attack Guidance Experiment (CAGE) was designed to assess such technology and TTPs.

This experiment consisted of a multinational (including American, Australian and Canadian operators) human-in-the-loop experiment based on a simulated Afghanistan scenario: all entities in the field were simulated and the participants filled Task Force Headquarters functions. A total of 33 experienced military operators participated in the experiment.

The experiment provided several results of interest to support current on-going operations as well as to orient future research activities. Various technical issues with regards to the integration of systems anticipated to be part of the evolving ISAF collapsed CENTRIXS (ISAF Mission Secret Network) were identified. In addition, improvements provided by new technology were assessed and recommendations for TTPs to support cross-coalition fires and battlespace management were made.

Introduction

Background

It has been argued that current airspace command and control is becoming more ineffective for several reasons including the broader use of unmanned aerial vehicles and the move towards a more non-linear and less contiguous battlefield (U.S. Army CCP 2008, 24). In addition, the air assets also belong to a broad variety of organizations: Army, Navy, Air Force, and Marines units from various coalition members as well as civilian agencies (more civilian flights or contracted flights are to be expected within the vicinity of combat areas – see U.S. Army CCP 2008, 24).

The broader usage of the airspace by a larger number of organizations as well as the broad need for coordination with ground maneuvers require a careful cross-coalition planning of the airspace usage. However, the process to react to immediate airspace needs requires several steps: airspace requests are submitted through numerous echelons of command for review, approval at the Airspace Control Authority level, publication through the Theatre Air-Ground System (TAGS) architecture and finally dissemination to users and implementation. This process is time consuming and not responsive enough to enable immediate actions necessary to support current operations (U.S. Army CCP 2008, 24). The required dynamic coordination across organizations for immediate action involves not only information sharing but some level of integration of procedures and intent (Lawrence and Lorsch defines "integration" as the process of achieving unity of effort among the various subsystems in the accomplishment of the organization's tasks—see Lawrence and Lorsch 1969a, 34). The Coalition Attack Guidance Experiment (CAGE) investigated the effectiveness of specific tools to support the cross-coalition usage of airspace.

Coalition Attack Guidance Experiment Aim

The aim of CAGE was to analyze airspace management, integration technologies and processes for opportunities to increase situational awareness throughout the chain of command to increase freedom of maneuver and effectiveness of Fires (i.e. shorten the targeting cycle, and reduce the potential for fratricide, collateral damage and civilian casualties) in a (coalition) operational context. More specifically, the experiment objectives were:

a. The assessment of the evolving ISAF collapsed network for coalition C2 and the potential impact on operations, personnel, and training;

b. An improved understanding of Joint Fires battlespace management and coalition environment;

c. An assessment of the Tactical Airspace Integration System (TAIS) and the Dynamic Airspace Coordination Tool (DACT) Concept of Employment (CONEMP) and Tactics Techniques and Procedures (TTPs);

d. The support of the Joint Fires Support Executive Steering Committee in identifying coalition joint fire issues (focusing on the integration of Intelligence, Surveillance and Reconnaissance (ISR), and Unmanned Aerial Vehicles (UAV) into Fires); and,

e. The advancement of the Canadian Joint Fires Support testbed to emulate coalition operations.

CAGE was a shared initiative between Defence Research and Development Canada's Joint Fires Support (JFS) Technical Demonstration Program (TDP) and The Technical Cooperation Program (TTCP) Aerospace Systems (AER) Technical Panel 1 (TP-1), as further supported by the United States Army's Aviation

and Missile Research and Development and Engineering Center (AMRDEC) and the Canadian Forces Experimentation Centre (CFEC). The experiment was held at CFEC from May 3 to 14, 2010.

Aim of the Article

The aim of this article is to provide an overview of CAGE and its relevance for assessing airspace management. An initial set of results is also provided. More specifically, the article first describes the theoretical framework and concepts used for developing the experimental assessment. The article then describes the experimental settings, the main observations from the experiment as well as initial results. The conclusion provides a summary and discusses future related work.

Main Concepts for the Experiment

Organizational Integration Overview

This section reviews the organizational integration model used for CAGE and described how this model was used to assess airspace management. The approach consisted in using a broad model that incorporates as much as possible all factors impacting on organizational integration with the aim of building the full problem space.

The concept of organizational integration plays an important role in a broad range of studies: organization theory (Thomson 1967; Lawrence and Lorsch 1969a; Galbraith 1974; Mintzberg 1989; Orton and Weick 1990), production/operations management (Burns and Stalker 1961; Carroad and Carroad 1982; Allen 1986), partnerships or inter-organization collaboration (Clelland and Finkelstein 1990; Osborn and Baughn 1990), and information systems (McCann

and Galbraith 1981; Cash, McFarlan, McKenney, and Vittale 1988; Earl 1989; Keen 1991). Common across these various studies are the aspects of coordination and collaboration across independent entities to achieve the desired integration level. However, beyond coordination and collaboration, integration implies the need for the various parties to know each other, understand mutual roles and levels of authority; share procedural knowledge as well as intent and expectations; and, to be responsive to each other needs (Orton and Weick 1990). Some of these more subtle aspects required for an effective integration have been sometimes overlooked.

Based on this approach to integration, Orton and Weick argued convincingly that integration cannot be interpreted using a simple unidimensional scale going from uncoupled to tightly coupled; a dialectic approach encompassing both the aspects of responsiveness and distinctiveness is needed. Using Orton and Weick definition, a system that is responsive but not distinct is defined as tightly coupled. If it is distinct and not responsive, it is decoupled. If a system is distinct and responsive, it is loosely coupled. Any complete measure of integration shall encompass both aspects of responsiveness and distinctiveness.

A 1992 study by Ettlie and Reza reviewed a large number of organizational integration studies. These studies were classified into four categories:

1. Contingency theory models of integration;

2. Integration of interdependent subunits;

3. Interfirm and interindustry integration;

4. Technological innovation opportunities.

These past studies largely focused on defining organizational integration, identifying the impact and benefits of organizational integration (such as innovation and higher productivity), and describing particular approaches within a given context (as explicit in the theses and findings indicated in column 3 of Table 1). Therefore these studies do not provide a cross-domain model that could be used to develop a systematic investigation of organizational integration. A first step in this direction was provided by Galbraith (1974) who mentioned three integration mechanisms: coordination by rules and programs; hierarchy (common supervision); and, coordination by targets or goals (common intent). Although he recognized additional mechanisms such as pre-planning, the addition of resources, the creation of self-contained tasks, the use of information systems, and the creation of lateral teams; the various mechanisms were not integrated within a single consistent model.

The recent model by Barki and Pinsonneault (Barki and Pinsonneault 2005) fills this gap by proposing a generic classification of type of organizational integration and associated level of effort, and by providing a list of factors that might hinder the integration as well as a list of mechanisms that support such integration. The success of this model was to incorporate the results from prior studies into a simple general model, which makes it an ideal tool for empirical analysis of data on organizational integration.

Table 1. Review of Organizational Integration Studies (Adapted from Ettlie and Reza 1992)

Issue	References	Theses and Findings
Contingency models of integration	Lawrence and Lorsch (1967)	Organizational differentiation and integration needed in turbulent environments
	Lawrence and Dyer (1984)	Re-adaption focuses on information complexity and resource scarcity
	Scott (1990)	Contingency model consistently supported, especially for subunits
Integration of interdependent subunits	Astley and Zajac (1990) Tjosvold (1990) Nemetz and Fry (1988) Kotha and Orne (1989) Susman (1990) Klein (1991) Baba (1989) Gerwin (1988) Collins et al. (1988) Souder and Padmanabhan (1989) Souder (1987) Gupta et al. (1987) Carroad and Carroad (1982) Hull and Azumi (1989)	Power relationships dependent on work flow, goal interdependence and interaction affect implementation of innovation Flexibility of operations required frequent schedule changes, high interdependence Just-in-time inventory systems, new technology, and standardization decrease individual autonomy but increase group autonomy Product and process innovation become prevalent in all industries, but barriers to R&D – production coordination are substantial R&D – marketing coordination and R&D multifunctional teamwork appear to be essential to successful innovation
Interfirm and interindustry integration	Clelland and Finkelstein (1990)	Interdependence of organizations in different economic sectors sets the stage for effective innovation strategy
	Granovetter (1985)	Economic action is embedded in social structure – alternative to vertical integration and a transaction cost perspective
	Osborn and Baughn (1990)	Form of interorganizational governance depends on R&D, technological intensity and size of parents firms
Technological innovation opportunities	Marcus (1988) Ginsberg and Buchholtz (1990)	Response to regulated change indicates that managers do have discretion to restructure, for nonroutine technologies
	Gerwin (1981)	Overlap of subsystems is likely as an alternative to hierarchical coordination
	Orton and Weick (1990)	Loose coupling in school systems reinterpreted in a dialectical model of coupling
	Markus and Robey (1988)	Evidence that information technology is an occasion for restructuring
	McCann and Galbraith (1981)	Multiple complementary strategies for interdepartmental coordination evident

Barki-Pinsonneault Model

Leveraging a large number of preceding studies, Barki and Pinsonneault (2005) proposed an Organizational Integration model (see Figure 1). The proposed model classifies the types of organizational integration into 6 categories and lists the various barriers to organizational integration as well as the integration mechanism. It also provides a list of 14 propositions to predict:

1. The level of effort needed to implement different types of organizational integration;

2. The impact different types of integration have on organizational performance;

3. The influence that six groups of factors (interdependence, integration barriers, integration mechanism, environmental turbulence, complexity reduction mechanisms, and organizational configurations) have on the relationship between organizational integration types, implementation effort, and organizational performance.

Only the primary elements of the model are described within this paper. The reader is referred to the Barki-Pinsonneault paper for more details.

The Organizational Integration is characterized based on the number of firms involved (internal: within a single organization; external: involving at least two firms) and on the type of integration: procedural (integration across procedures) or functional (integration by providing additional functionalities). (See column 1 of Figure 1)

Types of OI	Definition	Interdependence types	Barriers to OI	Mechanisms of OI	Integration effort	Potential benefits of OI
Internal	Integration within a firm					
Operational	Integration of successive stages within the primary process chain (workflow) of a firm	Sequential Reciprocal	(S-GD), (PO)	(PL), (DS), (SO), (SW), (MA)	High	• Greater manufacturing productivity • Greater firm competitiveness • Strategic advantages • Lower production and inventory cost • Reduced errors • Improved coordination
Functional	Integration of administrative or support activities of the process chain of a company	Pooled	(S-FD), (PO)	(SN), (SSK)	Low	• Products more attuned to market • Greater interfunctional synergy • Greater new product success • Higher innovation rate
External	Integration of at least two independent firms					
Operational						
Forward	Integration of successive process chain stages into distribution and retail	Sequential Reciprocal	(S-GD)	(PL), (DS), (SO), (SW), (MA)	Very High	• Economies of scale/scope • Higher sales • Higher switching costs • Faster introduction of new products • Faster delivery of products
Backward	Integration of successive process chain stages into supply	Sequential Reciprocal	(S-GD)	(PL),(DS), (SO), (SW), (MA)	Very High	• Economies of scale/scope • Reduced shipment discrepancies • Faster introduction of new products • Faster payment • Reduced credit
Lateral	Integration of successive process chain stages into components or parts	Sequential Reciprocal	(S-GD)	(PL), (DS), (SO), (SW), (MA)	Very High	• Economies of scale/scope • Greater manufacturing productivity
Functional	Integration across firms of administrative or support activities	Pooled	(S-FD)	(SN), (SSK)	Moderate	• Lower administrative overhead costs • Higher decision quality • Downsizing

Notes. OI Barriers: S-GD specialization, goal differences; S-FD specializaton, frame differences; PO, political considerations. OI Mechanisms (Glouberman and Mintzberg 2001, Mintzberg 1989, Thompson 1967): MA, mutual adjustment; DS, direct supervision; SO, standardization of output; SW, standardizaton of work; SSK, standardization of skills and knowledge; SN, standardization of norms; PL, planning.

Figure 1. Barki and Pinsonneault Organizational Integration Model (2005)

The Barki and Pinsonneault model also includes the type of interdependency as introduced by Thomson (1967). Three types of interdependencies were introduced by Thomson: Pooled, Sequential or Reciprocal (see column 3 of Figure 1). Pooled interdependency is the simplest and corresponds to the functional integration where the various integrated organizations share common pooled resources. Sequential interdependency implies that the output of one organization is used as input by the other. The reciprocal interdependency is the most complex and implies back and forth procedural interaction between the organizations.

Barki and Pinsonneault also identified various barriers (column 4 of Figure 1) and mechanisms for integration (column 5 of Figure 1) as well as the required level of effort (column 6 of Figure 1) for the various kinds of organizational integration (the reader is referred to the original paper of Barki and Pinsonneault for a discussion of these aspects of their model). Note that Barki and Pinsonneault's proposed mechanism for integration assumes that no organization change will

occur (i.e., it does not explicitly mentions the creation of liaison officers and integrating teams – however, such mechanisms only divide the integration problem and can lead to lower responsiveness).

Finally, the concept of "degree of effort" used in this model is similar to the one used in St-Arnaud organizational description which is based on the concept of thermodynamics. This latter model states that the degree of effort corresponds to the energy required to establish order within the system. The higher the required coordination is, the higher the effort will be.

Organizational Integration for Airspace Management

The Barki-Pinsonneault model was used for two reasons: 1) to assess the level of efforts required to support the integration of the organizations involved in airspace management; and, 2) to ensure a systemic data collection and analysis for CAGE. With regards to the required level of efforts, the Barki and Pinsonneault model ranks the difficulties for a dynamic response to an immediate request for airspace use among the most complicated category of organizational integration. First, the integration involves a very large number of organizations from various countries and possibly international organizations (NATO, United Nations, etc.). In support of this statement, Figure 2 shows the various US military units involved in Air-Ground operations. Each service are shown using different colors: purple for joint, green for army, blue for air force, red for marines, gray for navy, and black for the special forces. (Note that this figure is only provided as a reference point and no explicit description is provided – for more details, the reader is referred to AFTTP3-2.17, 2007). The large number of units and organizations involved complicates largely the identification of Points of Contact.

From the point of view of Barki and Pinsonneault model, the possible presence of organizations from various countries including both civil and military organizations implies an External integration.

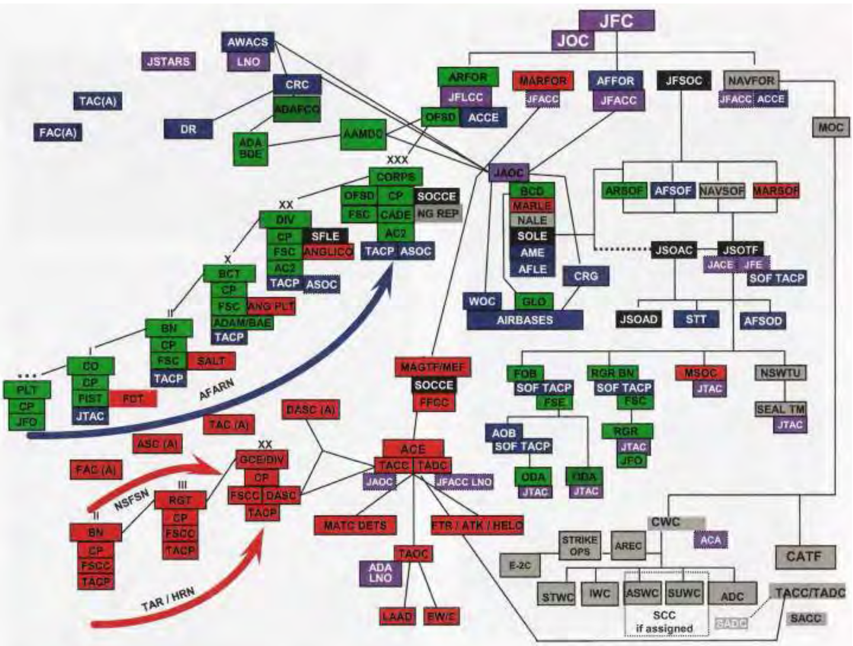

Figure 2. Overview of the US Theatre Air-Ground System (TAGS)

Second, the required type of integration is both operational and lateral. Although some military air assets might be pooled together, because of the limited airspace, the integration of airspace users require integration beyond the simple sharing of pooled assets: the airspace usage needs to be coordinated.

Third, the required integration is reciprocal. A back and forth coordination across airspace users is required.

Finally, military operations are provisional. Therefore, one deals with a temporary situation where organizations need to learn each other's procedures, technical settings and organizational structure for a set period of time. Furthermore, staff members from various organizations often rotate and the same staff could remain in a certain position for only six months.

Looking at the Barki and Pinsonneault indicated level of effort, which does not explicitly take into account the provisional nature of the organizational integration and the staff rotation, it is clear that the required level of effort for integration is very high (see Figure 1, row 5 and column six).

Airspace Management Integration

Many of the integration mechanisms identified within the Barki-Pinsonneault model are currently being used to some degree to support the airspace management. For example, many military organizations embed liaison officers or liaison teams (for example, the ASOC and TACP in Figure 2 are air force liaison teams embedded in an army unit) that will support a standardization of norms, knowledge and skills. Standards for skills, knowledge and work (doctrine) are also commonly used (e.g., NATO standards). Furthermore, planning is a well-used mechanism since airspace integration is performed both at the planning and execution level.

More specifically, airspace management includes two types of procedures: positive control and procedural control. Positive control implies near-real time tracking and direct identification of air assets using radars, other sensors, digital data links, and other Command and Control and Communication systems. On the other hand, procedural control is performed by relying on established and promulgated Air Coordination Measures (ACM) developed in the planning of the operations.

However, the current procedural control method for aviation assets is largely static and does not support an agile force. Aviation missions are provided with a fixed set of ACMs before departure and aviation pilots maneuver using largely static geometries (on-going projects are aiming at solving these issues—see LtCol Wathen 2006). In the case of a crowded airspace, this implies a constant usage of narrow corridors. It follows that the aviation routes become more predictable,

leading to an increased risk for these assets. Therefore, two aspects, in addition to organizational integration, can be improved: the ability for the aviation pilot to receive updated ACMs in a timely fashion that would lead to a less static airspace; and, a reduced size of the ACMs to lead to an increase freedom of maneuver.

CAGE Design

Experiment Aim

As previously mentioned, the aim of CAGE was to analyze airspace management and integration technologies and processes for opportunities to increase situational awareness throughout the chain of command, to increase freedom of maneuver and effectiveness of Fires (i.e. shorten the targeting cycle, and reduce the potential for fratricide, collateral damage and civilian casualties) in a coalition operational context. More specifically, CAGE was a human-in-the-loop experiment, utilizing experienced operations personnel, and a representative Afghanistan scenario setting. The system, organizational and procedural foci were:

a. Systems focus: US Army Battle Command systems including the Tactical Airspace Integration System (TAIS), Dynamic Airspace Collaboration Tool (DACT) and the Joint Automated Deep Operations Command System (JADOCS). The complete list of systems is provided in Annex A;

b. Organizational focus: The operational context was primarily focused on joint and multinational military operations, with civilian infrastructure limited to the simulation of Afghanistan ground based radar commercial traffic. Specific operators within the Canadian Task Force Kandahar (TFK),

US Task Force Pegasus (TFP), NATO Regional Command – South [RC(S)] and the Kandahar Control and Reporting Centre (CRC) were manned for the experiment; and,

c. Procedural focus: Joint and multinational military operations were focused on joint fires coordination and airspace management at the operational and tactical headquarters level across the coalition where the evolving C2 configuration intended for ISAF will be employed by the coalition partners.

Compared Conditions

CAGE was split into two conditions. Condition 1 consisted of current operations, which did not include the use of the DACT. TFK/TFP/RC(S) airspace interactions consisted of the exchange of text chat and shared folders. TFK primarily used JADOCS. TFP used TAIS. RC(S) used JADOCS and ICC (NATO Integrated Command and Control). This first condition simulated the planned ISAF C2 Collapsed configuration (systems network and communication links planned for Kandahar, Afghanistan).

In Condition 2, the DACT was introduced at all levels. Users were able to visualize current and emerging airspace and near-real-time air-tracks to assist them in making decisions.

During both conditions the airspace coordination TTPs were based on the use of the Global Area Reference System (GARS). The comparison of both experimental conditions was used to test the following experiment hypothesis:

> Experiment Hypothesis. The provided collaborative tools lead to an enhanced integration across coalition partners to better manage and deconflict airspace usage.

From the point of view of the Barki-Pinsonneault model, most integration mechanisms are considered fixed between the two conditions except for the shared knowledge (standardization of knowledge) and the ability for mutual adjustment.

Manning and Layout

Military staff from Canada, United States as well as from Australia performed designated roles, which consisted of a reduced Canadian Joint Task Force Tactical Operations Centre (TFK TOC), an All-Source Intelligence Cell (TFK ASIC), U.S. Air Defence Airspace Management (TFP ADAM) cell as well as specific air coordination roles within the NATO Regional Command South (RC(S)) Headquarters and the airspace Control Reporting Centre (CRC). The experiment did not include a fully manned TOC, ADAM cell and RC(S) HQ. Only the positions most relevant to air and ground fires were manned.

Additional personnel provided experiment control, data collection and technical support to the experiment. Experiment control personnel created and manipulated computer generated forces to stimulate the on-going battle and activities of field units. All the field units were simulated; there were no real assets external to the headquarters used during the experiment.

Figure 3 displays the layout of the Joint BattleLab as set up for CAGE. The participants were located in two different buildings. The main building included the TOC (yellow area), the ASIC and the ADAM cell (both in the blue area). The participants filling RC(S) and CRC roles were located in a small trailer adjacent to the main JBL. The experiment control staff was distributed between the main JBL (gray area) and the small trailer. Finally, the team of 13 observers was distributed across both buildings observing the target audience activities and interaction.

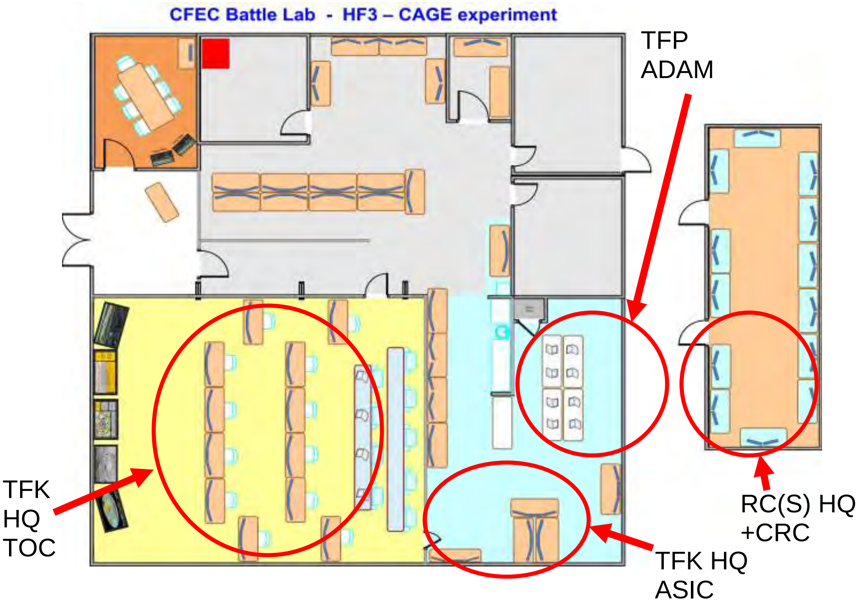

Figure 3. Layout of the Joint BattleLab During CAGE

Experiment Schedule

Several weeks of technical testing and evaluation were performed prior to the two weeks of experimentation to ensure an adequately designed set of tools. When the operators arrived for the experiment, they received two days of briefings and training with the various tools provided to them. The briefings provided background information on the aims of the experiment and on the scenario that was used for the experiment. The third day was allocated for the operators to rehearse the processes and get to learn each other roles. During this day, the participants developed procedural conventions (e.g., the convention on the meaning of various colored icons in JADOCS) as well as some products required for the airspace management (Airspace Coordination Measures and Fires Coordination Measures). These first three days were then followed by three days

of testing of condition 1. The following week started with one Distinguished Visitor Day followed by three days of testing of condition 2 and one day of after-action review.

Experiment Scenario

The scenario was set in current day Afghanistan. It focused on battle management events associated with the need for joint fires support, intelligence assessment and airspace management that required coordination across the operational and tactical level headquarters within RC(S) and with national command elements. The injection of events and data to test and evaluate specific systems, operators and TTPs evolved in three phases:

a. Phase I involved the insertion of Canadian Task Force Kandahar (TFK) troops by US aviation assets to conduct a cordon and search of a possible insurgent camp;

b. Phase II required friendly forces to hold ground after the insurgent camp/stronghold had been successfully taken over as a Forward Operating Base. Enemy forces conducted "hit and run" engagements on the TFK forces and logistics convoys; and,

c. Phase III consisted of a high intensity conflict comprised of dynamic events requiring immediate coordination and execution as the enemy hit the Forward Operating Base from all directions using all weapons in their arsenal.

An intelligence estimate and relevant operational order extracts were developed as part of the background-reading package. Each incident was supported by a quantity of representative information typical of the level of information that would be expected by the headquarters.

Data Collection and Measures

A large amount of data was collected during the experiment. The data collected included observations on the systems integration and operators' activities (13 observers participated) , the constant monitoring of all workstation activities (keystrokes and mouse-clicks), the logs of the information exchanged through chat and radio, and the responses to specific questionnaires distributed to operators twice daily. In addition, lessons were captured with regards to the technical issues identified.

The primary measures of effectiveness was developed using the Barki-Pinsonneault model. As aforementioned, some integration mechanisms were considered fixed throughout the experiment: direct supervision, the standardization of work (based on GARS grid), the standardization of skill (which was assessed by gathering background information on the operators), and the planning (preselected Airspace Coordination Orders and Air Tasking Orders). The main variables expected to vary between both conditions were the level of mutual adjustment, the standardization of the work outputs that depended on the tools integration, the standardization of knowledge, and the standardization of norms which is expected to adjust to the condition (with better performing tools, higher norms are expected). The measures focused on assessing the outcome expected from organizational integration (the responsiveness to cross-organizations requests), as well as the variables expected to vary between the conditions (the mutual adjustment, outputs, and knowledge standardization). More precisely, the following measures were assessed:

a. The responsiveness of the various organizations in responding to immediate requests for airspace clearance (measured in minutes);

b. The level of procedural integration (number of mutual adjustment observed);

c. Effectiveness of fires support decision making, based on how quickly targets were processed, and engaged once they had been identified (measured in minutes); and,

d. System integration and tools' usability along with input from the operators and technical subject matter experts, to identify issues with the software systems that enhance or degrade the operators' ability to perform the targeting and airspace management tasks (open ended questions).

Preliminary Results and Discussion

Only an overview of the main results is provided in this paper. Note that technical issues with the collaborative module of DACT limited the analysis to anecdotal evidence: DACT was used only on a few occasions within Condition 2 and therefore no statistical analysis of the results was possible.

Airspace Management Information Flow

During mission execution, the TFK and TFP operators in charge of requesting airspace clearance would construct and transmit the Airspace Coordination Measures Requests (ACMRs) to the TAIS operator. Once the TAIS operator has assessed the requests, and has provided any appropriate feedback to the requestor, he would then send those ACMRs to RC(S) (via exported flat-files over shared network folders) for the RC(S) ASCC to deconflict and clear. RC(S) ASCC would load the received ACMR into ICC and would assess the requests in the context of the current theatre airspace control order (ACO) and existing TFK/TFP/RC(S) airspaces that were considered hot. RC(S) ASCC would then communicate approval or denial back down the channel. For ACMRs over 11,500 ft, RC(S) ASCC communicated with the CRC personnel and asked if that airspace is physically cleared of aircraft. In most cases, the CRC

communicated with the relevant air control and coordinated the redirection of the aircraft in conflict and then communicated that the airspace was clear back to RC(S).

Table 2 shows the number of airspace management related communication initiated for each experimental day and the average number of words for each communication. These results indicate that the DACT did not lead to a reduction of the amount of communication nor were the communication reduced in terms of number of words. However, these results might be due to the technical difficulties experienced during Condition 2 and more investigation would be required for definitive results.

Table 2. Number of Airspace Management Related Communications

	# of Communications Initiated	Average # Words Per Communication
Condition 1, Day 1	386	10.1
Condition 1, Day 2	408	10.4
Condition 1, Day 3	240	10.5
Condition 2, Day 1	361	11.7
Condition 2, Day 2	127*	10.4
Condition 2, Day 3	236	11.6

*Due to visitors that impeded on the experiment

System Integration and Evolving ISAF Collapsed Network

With regards to the integration of the various systems several results of interest were obtained. These results include observations on the integration of ICC with TAIS and TBMCS; the transfer of data between LCSS and JADOCS; and, the integration of US Army Battle Command systems using PASS (the Publish And Subscribe Server).

There were abundant functional, architectural and technical issues with ICC. Functional issues included the non-existence of capability to automatically transmit or process digital airspace information: ICC does not support the concept of an external airspace coordination request (ACR); too many requirements for manual export of data to a file; and, there does not appear to be a mechanism for packaging and digitally transmitting changes to the ACO to TBMCS. ICC also used both long and short names for the air coordination measures (ACMs). However, only the short names could be exported causing confusion between operators. Furthermore, when an ACO is imported into TAIS, any extra non-USMTF formed text introduced in ICC could not be loaded in TAIS and the complex shape PolyArc defined in a USMTF message read into ICC was drawn with incorrect point order. Less reliance on ICC during Condition 2 led to an perceived improved technical integration for the RC(S) participants.

Similar functional and technical issues to link the Land Command Support System (LCSS) with JADOCS were encountered. In particular, it was discovered that if the LCSS problems with OTH-Gold message were fixed and the additional information fields added to the message it would be possible to pass the Canadian Blue picture to the Afghan Mission Network (AMN) and to add the blue picture from the AMN to LCSS. However, this passing of information would not be perfect and would differ from the operators' expectation in three important ways:

- Some information like the echelon level and the unit type did not flow into JADOCS leading to unspecified units being displayed on the Common Operating Picture.

- The LCSS ODB did not update when the location of ground troops did not change. This led to operators having a picture which they thought was not current. They questioned the validity of the blue picture and did not trust it.

- The LCSS OTHGMD truncated the precision of unit locations so the Common Operating Picture presented in JADOCS differed and was less accurate than that presented in LCSS Battleview.

It is clear from these observations that more technical work is required to ensure a proper technical integration across coalition organizations. Technical standards and common philosophies on the evolution and management of these standards are required.

Procedural Integration

Various procedures were elaborated and further developed during the experiment. In particular, the usage of the SigAct Manager was refined and improved as the experiment went on. The refinement of common procedures was initiated during the rehearsal day and contributed to a more effective integration across the TFK, TFP and RC(S). Particular observations with regards to procedural integration include:

- Business rules with regards to the utilization of chat and support for the use of operational terminology were lacking. Chat rooms were considered by several as an inappropriate communication tool. On a few occasions, some operators copied long lists of information into the text chat which resulted in breaking the on-going information sharing. The operators then had to continuously scroll up and down to refer back to previous thread of information. Furthermore, on several occasions, operators answered questions posted into the chat room without specifying which question was being answered. On a few occasions, this led to confusion among operators.

- The use of Global Area Reference System (GARS)[1] grids (for both conditions) provided an effective cross-coalition airspace management. The TFK ASCC used a JADOCS *OpsBox Manager* to construct airspaces based on the GARS grid, and would communicate those grids over chat and VOIP. These grid values would quickly and easily be communicated to the CRC for rapid clearance. Limitations on the TAIS and JADOCS prevented quick construction of ACMRs based on GARS grids. These limitations were overcome fairly well, either by manually drawing the GARS based geometry, or using pre-constructed ACMRs.

- In Condition 1, for complex fire missions, the auto-generated ACMRs sent to ICC from TAIS could be brought up on ICC. Lacking adequate 3D visualization in Condition 1, the most effective way for the CRC to ensure a clear airspace was to breakdown the space into GARS keypads, and then request clearance of the required keypads.

- Once the DACT was introduced as part of Condition 2, RC(S) and CRC were able to work efficiently in concert, sharing the same airspace picture, giving them access to full 3D visualization with terrain, and giving them access to a very detailed simulated air-picture. CRC greatly benefited from the 3D visualization of the aircraft in the context of the 3D airspace volumes. According to the CRC and RC(S) players, they were better able to discern aircraft/airspace conflicts originating from the submitted ACMR and DACT also reduced their workload reducing the number of manual imports and exports between systems.

1. GARS divides the world in 30 minutes by 30 minutes cell. Each cell is subdivided in quadrants (4 quadrants per cell) and each quadrant into keypads (9 keypad units per quadrant).

Integration Level Effectiveness

Overall good collaboration across the TFK, TFP and RC(S) was observed during the experiment. On a few occasions, some operators were dissatisfied with the responsiveness of operators from external organizations. The lack of responsiveness was partially due to external visitors who were given a tour of the Joint BattleLab outside of the visitors' day (for both conditions). However, within condition 1, there are also indications that some complications in using the ICC were responsible for delays observed. When receiving a proposed change to the ACO, the RC(S) ASCC had to open a new ACO editor in ICC, import the proposed change, and then copy and paste the ACMs into their working unit airspace plan. The proposed ACO would then be checked for conflict, communicated to the CRC for positive clearance and approved or not, depending on possible conflict. All these operations required additional time and led to a lower satisfaction of the operators with regards to the other organizations responsiveness.

However, under conditions 2, the RC(S) task was greatly facilitated and shortened by the introduction of DACT (although DACT was not meant to replace ICC, the RC(S) ASCC hardly used ICC during the second week). Several participants also indicated better cross-organization integration through the capacity provided in Condition 2 to keep track of the status of submitted ACMR.

Furthermore, although most TFK operators were less satisfied with the overall information sharing during condition 2, the three TFK operators directly involved in airspace management were unanimous in indicating an improved information sharing during condition 2. Although precise statistics are not possible due to the small sample size, these results were indicative of improved inter-organizational integration due to DACT support.

Conclusion

The results from CAGE indicate that although no improvement in the outcome in organizational integration was obtained, this integration was easier in Condition 2 than in Condition 1. More precisely, the results indicated that systems such as DACT support mutual adjustment (through the use of automated conflict assessment tools to ensure adjustment of airspace usage), standardization of outputs (standards more compatible with the various systems used within CAGE) and knowledge (through the capability to track ACMR status). However, the Barki and Pinsonneault model highlights that other integration mechanisms (direct supervision, standardization of work, standardization of skills, and planning) can be employed to support organizational integration. Although, such mechanisms were not investigated within CAGE, these other mechanisms should not be overlooked. In other words, the organizational integration does not entirely depend on technical solutions and standards; training, organizational structure and robust tactics, techniques and procedures are required.

Several past studies on organizational integration were largely limited to the consideration of tasks, information sharing and technical aspects of the integration. The current paper extends this consideration by using a formal organizational integration model. Due to technical issues, the experimental results only had limited value, but future works and in particular an upcoming CAGE II experiment, will aim at providing a more rigorous investigation using the Barki-Pinsonneault model.

References

Allen, T.J. 1986. *Managing the Flow of Technology.* Cambridge, MA: MIT Press.

Astley, W. G. and E. J. Zajac. 1990. Beyond Dyadic Exchange: Functional Interdependence and Sub-unit Power. *Organization Studies* 11: 481-501.

Baba, Y. 1989. The Dynamics of Continuous Innovation in Scale-Intensive Industries. *Strategic Management Journa*l 10: 89-100.

Barki, H. and A. Pinsonneault. 2005. A Model of Organizational Integration, Implementation Effort, and Performance. *Organization Science* 16(2): 165-179.

Burns, T. and Stalker, G.M. 1961. *The Management of Innovation*. London: Tavisock.

Carroad, P. A. and C. A. Carroad. 1982. Strategic Interfacing of R&D and marketing. *Research Management* 25(1): 28-33.

Cash, J.I., Jr., F.W. McFarlan, J.L. McKenney, and M.R. Vitale. 1988. *Corporate Information Systems Management* 2nd ed .Homewood, IL: Irwin.

Clelland, I. and S. Finkelstein. 1990. Structural Interdependence and Organizational Response to Technological Innovation. Proceedings of *Strategic Leadership in High Technology Organizations*, Boulder, CO: 51-55.

Collins, P. D., J. Hage, and F.M. Hull. 1988. Organizational and Technological Predictors of Change in Automaticity. *Academy of Management Journal* 31: 512-543.

Earl, M.J. 1989. *Management Strategies for Information Technology.* Englewood Cliffs, NJ: Prentice Hall.

Ettlie, J.E. and E.M. Reza. 1992. Organizational Integration and Process innovation. *Academy of Management Journal* 35(4): 795-827.

Galbraith, J.R. 1974. Organization Design: An Information Processing View. *Interfaces* 4: 28-36.

Galbraith, J. R. 1977. *Organization Design*. Reading, MA: Addison-Wesley.

Gerwin, D. 1981. Relationships Between Structure and Technology. In *Handbook of Organizational Design* vol. 2: 3-38, eds. P. C. Nystrom and W. H. Starbuck. New York, NY: Oxford University Press.

Gerwin, D. 1988. A Theory of Innovation Process for Computer-aided Manufacturing Technology. *IEEE Transactions on Engineering Management* 35: 90-100.

Ginsberg, A. and A. Buchholtz. 1990. Converting to For-profit Status: Corporate Responsiveness to Radical Change. *Academy of Management Journal* 33: 445-477.

Glouberman, S. and H. Mintzberg. 2001. Managing the Care of Health and the Cure of Disease - Part II: Integration. *Health Care Management Review* 26(1): 70-84.

Granovetter, M. 1985. Economic Action and Social Structure: The problem of embeddedness. *American Journal of Sociology* 91: 481-510.

Gupta, A. K., Raj, S. P., and Wilemon, D. 1987. Managing the R&D-Marketing Interface. *Research Management* 30(2): 38-43.

Hull, F. M. and Azumi, K. 1989. Teamwork in Japanese and U.S. Labs. *Research and Technology Management* 32(6): 21-26.

Keen, P.G.W. 1991. *Shaping the Future: Business Design through Information Technology*. Boston, MA: Harvard Business School Press.

Klein, J. A. 1991. A Reexamination of Autonomy in Light of New Manufacturing Practices. *Human Relations* 44: 21-38.

Kotha, S. and D. Orne. 1989. Generic manufacturing strategies: A conceptual synthesis. *Strategic Management Journal* 10: 211-231.

Lawrence, P. R. and D. Dyer. 1984. *Renewing American Industry*. New York, NY: Free Press.

Lawrence, P.R. and J.W. Lorsch. 1969a. *Organization and Environment*. Boston, MA: Harvard Business School Press.

Lawrence, P.R. and J.W. Lorsch. 1969b. *Developing Organizations: Diagnosis and Action*. Boston, MA: Addison-Wesley Publishing Company.

Marcus, A. A. 1988. Responses to Externally Induced Innovation: Their Effects on Organizational Performance. *Strategic Management Journal* 9: 387-402.

Markus, M. L. and D. Robey. 1988. Information Technology and Organizational Change: Causal Structure in Theory and Research. *Management Science* 34: 583-598.

McCann, J. and J.R. Galbraith. 1981. Interdepartmental Relations. In *Handbook of Organizational Design* vol. 2: 60-84, ed. P. C. Nystrom and W. H. Starbuck. New York, NY: Oxford University Press.

Mintzberg, H. 1989. *The Structure of Organizations*. Prentice Hall, Englewood Cliffs, NJ.

Nemetz, P. L. and L. W. Fry. 1988. Flexible Manufacturing Organizations: Implications for Strategy Formulation and Organizational Design. *Academy of Management Review* 13: 627-638.

Orton, J. D. and K. E. Weick. 1990. Loosely Coupled Systems: A Reconceptualization. *Academy Management Review* 15(2): 203-223.

Osborn, R. N. and C. C. Baughn. 1990. Forms of Interorganizational Governance for Multinational Alliances. *Academy of Management Journal* 33: 503-519.

Scott, W. R. 1990. Technology and Structure: An Organization-level Perspective. In *Technology and Organizations,* ed. P. S. Goodman, L. S. Sproull, and Associates. San Francisco, CA: Jossey-Bass.

Souder, W. E. 1987. *Managing New Product Innovations.* Lexington, MA: Lexington Books.

Souder, W. E. and V. Padmanabhan. 1989. Transferring New Technologies from R&D to Manufacturing. *Research and Technology Management* 32(5): 38-43.

Souder, W.E., J.D. Sherman, and R. Davies-Cooper. 1998. Environmental Uncertainty, Organizational Integration, and New Product Development Effectiveness: A Test of Contingency Theory. J. Prod. I*nnovation Management 1*5: 520-533.

Susman, G. I. 1990. Work groups: Autonomy, Technology, and Choice. In *Technology and Organizations,* ed. P. S. Goodman, L. S. Sproull, and Associates, San Francisco, CA Jossey-Bass.

Thompson, J. D. 1967. *Organizations in Action: Social Science Bases of Administrative Theory*. New York, NY: McGraw Hill.

Tjosvold, D. 1990. Making a Technological Innovation Work: Collaboration to Solve Problems. *Human Relations* 43: 1117-1131.

U.S. Army Concept Capability Plan (CCP) 2008. Airspace Command and Control. *TRADOC Pamphlet* 525.

U.S. Air Force. AFTTP3-2.17_IP 2007. *Multi-service Tactics, Techniques, and Procedures for the Theatre Air-ground System*. Air Land Sea Application Center.

Wathen, Alex. 2006. Joint Airspace Management and Deconfliction - A Chance to Trade in a Stovepipe for Network Centric Warfare. *Air and Space Power Journal* Fall 2006.

Acronyms

ACM	Airspace Coordination Measure
ACMR	Airspace Coordination Measure Request
ACO	Airspace Control Order
AFATDS	Advanced Field Artillery Tactical Data System
ATO	Air Tasking Order
ADAM	Air Defense and Airspace Management
AER	Aerospace
AMRDEC	Aviation and Missile Research, Development and Engineering Centre
ASIC	All-Source Intelligence Cell
C2	Command and Control
CAGE	Coalition Attack Guidance Experiment
CENTRIXS	Combined Enterprise Regional Information Exchange System
CFEC	Canadian Forces Experimentation Centre
CONEMP	Concept of Employment
CRC	Control and Reporting Centre
DACT	Dynamic Airspace Collaboration Tool
ExCIS	Extensible C4I Instrumentation System

GARS	Global Area Reference System
GCCS-M	Global Command and Control System - Maritime
HQ	Headquarters
ICC	Integrated Command and Control
ISAF	International Security Assistance Force
ISR	Intelligence, Surveillance and Reconnaissance
JADOCS	Joint Automated Deep Operations Coordination System
JCATS	Joint Conflict and Tactical Simulation
JFS	Joint Fires Support
JSAF	Joint Semi-Automated Forces
JTT	Joint Targeting Toolkit
LCSS	Land Command Support System
MFP	Missile Flight Path
MIDB	Modernized Integrated Database
NATO	North Atlantic Treaty Organization
ODB	Operational Database
OneSAF	One Semi Automated Forces
OTH-G	Over-The-Horizon – Gold
OTHGMD	Over-The-Horizon Gold Message Dispatcher

PASS	Publish and Subscribe Server
RC(S)	Regional Command (South)
TADIL	Tactical Digital Information Link
TAIS	Tactical Airspace Integration System
TBMCS	Theatre Battle Management Core System
TDP	Technology Demonstration Program
TFK	Task Force Kandahar
TFP	Task Force Pegasus
TIMS	Tactical Information Management System
TOC	Tactical Operations Centre
TP	Technical Panel
TTCP	The Technical Cooperation Program
TTP	Tactics, Techniques and Procedures
UAV	Unmanned Aerial Vehicle
VBS	Virtual Battlespace

Annex A – Experimental Systems

For CAGE, the operators relied on a number of integrated C2 systems, services and tools. The C2 systems and associated communications and interface service applications included:

- The Joint Automated Deep Operations Coordination System (JADOCS) is a joint mission management software application that provides an integrated set of functional capabilities for data analysis and management, mission planning, coordination and execution of a variety of joint tasks.

- The Land Command Support System (LCSS) is a system of systems that integrates all the tools that Army commanders need to effectively direct troops in all phases of military operations (e.g., BattleView, Orion, TIMS) and provides enhanced Blue Positional Awareness.

- The Global Command and Control System - Maritime (GCCS-M) is a single, integrated, scalable Command, Control, Communications, Computers, and Intelligence (C4I) system that receives, displays, correlates, fuses and maintains geo-locational track information on friendly, hostile and neutral land, sea and air forces and integrates it with available intelligence and environmental information.

- The Tactical Battle Management Core Systems (TBMCS) is the primary system for planning and executing the joint air campaign, coordinating and directing flying operations.

- The Tactical Airspace Integration System (TAIS) is an Army's hardware/software mobile system for the integration and synchronization of Airspace Management and Air Traffic Services that provides combined air-ground battlespace management based on joint service information system inputs.

- The Dynamic Airspace Collaborative Tool (DACT) is a web-based application which gives operators the ability to display Airspace Control Order and Airspace Coordination Measures (under the constraint that they are provided from a TAIS user) and collaborate among them or with TAIS operators for the establishment of new Airspace Coordination Measures.

- The Command Post of the Future (CPoF) is an executive level decision support collaborative system that provides situational awareness and collaborative tools to support decision making, planning, rehearsal and execution management.

- The Advanced Field Artillery Tactical Data System (AFATDS) is a multi-service (Army, Marine Corps, Navy), Joint and combined forces fire support Command, Control and Communications (C3) system that provides the Commander tools including Situational Awareness (SA), Battle Management, Target Analysis and Target Engagement.

- The Integrated Command and Control (ICC) is an integrated Command, Control, Communications, and Intelligence (C3I) system that provides information management and decision support to North Atlantic Treaty Organization (NATO) Combined Air Operations Centre (CAOC) level air operation activities during peacetime, exercise and wartime.

- The Joint Targeting Toolkit (JTT) is a set of tools that provides Automated Targeting Folders, Target Planning Worksheets, Battle Damage Assessment, and Automated/Plotted Targets. It also allows the intelligence analysts to update the Modernized Integrated Database (MIDB).

- The Publish and Subscribe Server (PASS) is an Army publish and subscribe feature that allows for greater horizontal integration among Army battle command systems and interoperability outside the Army and opens the door for interoperability with the other services and with coalition forces.

- The Air Defense Systems Integrator (ADSI) is a suite of automated communications equipment capable of receiving and transmitting messages in a variety of Tactical Digital Information Link (TADIL) formats and capable to display and exchange air picture, intelligence and other tactical information with Joint and Army systems.

The following applications were used to simulate the required virtual environment:

- The Joint Conflict and Tactical Simulation (JCATS) program is an interactive simulation tool that provides a wide range of operations in a variety of dynamic simulated environments and allows the modeling of the dynamics of individual soldiers, vehicles, and weapons.

- The Joint Semi-Automated Forces (JSAF) is a simulation system that generates entity-level simulations which interact individually in a synthetic environment (individual entities include infantrymen, tanks, ships, airplanes, munitions, buildings, and sensors that can be controlled separately or organized into appropriate units for a given mission).

- The One Semi-Automated Forces (OneSAF) is a simulation software system that allows users to configure computer generated force systems and includes military models such as United State Marine Corps, Naval systems and civilian models for civilian infrastructure, normal civilian behavior, and terrorist/insurgent behavior.

- The Virtual BattleSpace 2 (VBS2) is an interactive, three-dimensional simulation system providing a synthetic environment suitable for a wide range of military (or similar) training and experimentation purposes that offers realistic battlefield simulations and the ability to operate land, sea, and air vehicles, create scenarios and engage simulations from multiple viewpoints.

- The Extensible C4I Instrumentation System (ExCIS) allows the development of constructive simulations of Field Artillery / Fire Support entities from individual sensors and weapons systems and provides realistic operational environments for Field Artillery / Fire Support Command and Control systems.

In addition to the C2 systems and simulation applications the operators had access to a standard set of office tools (MS-Office) and communication tools for chat (mIRC), simulated radio (SimSpeak) and Voice Over Internet Protocol (VOIP).

Figure 4 illustrates how the systems and tools are linked and how the operators will interact with them.

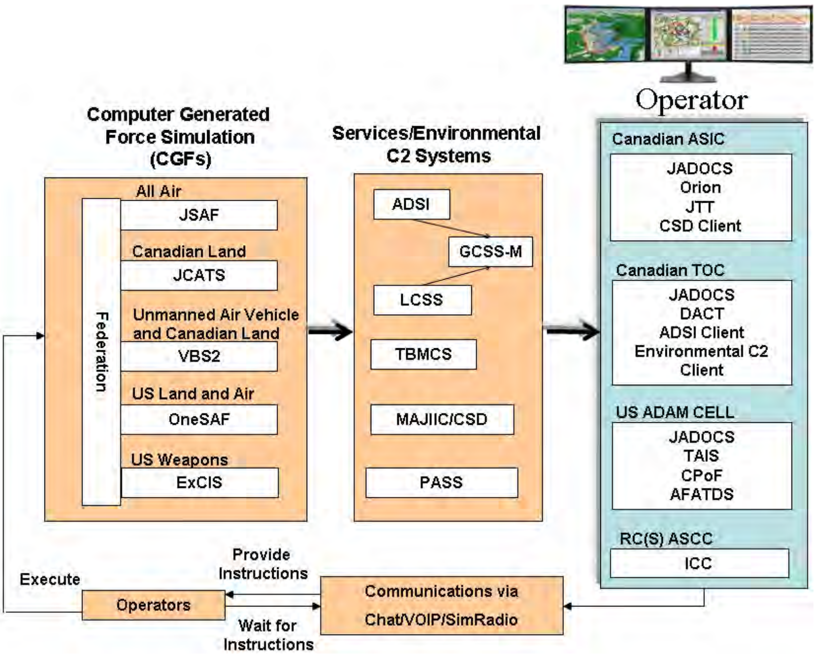

Figure 4. Experiment System and Tools